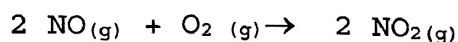


CHM129
Gibbs Free Energy

1. Use $\Delta G^\circ_{\text{Rxn}}$ to determine whether the process is spontaneous. Calculate the value of the equilibrium constant, K .



	ΔH°_f (kJ/mol)	S° (J/mol.K)
NO	+90.29	+210.65
O ₂	0	+205.0
NO ₂	+32.2	+239.9

$$\Delta H^\circ_R = \sum n \Delta H^\circ_{f \text{ prod}} - \sum n \Delta H^\circ_{f \text{ react}}$$

$$= (2 \text{ mol} \times 32.2 \text{ kJ/mol}) - [(2 \text{ mol} \times 90.29 \text{ kJ/mol}) + (1 \text{ mol} \times 0 \text{ kJ/mol})]$$

$$\Delta H^\circ_R = -116.2 \text{ kJ}$$

$$\Delta S^\circ_R = \sum n S^\circ_{\text{prod}} - \sum n S^\circ_{\text{react}}$$

$$= (2 \text{ mol} \times 239.9 \text{ J/mol.K}) - [(2 \text{ mol} \times 210.65 \text{ J/mol.K}) + (1 \text{ mol} \times 205.0 \text{ J/mol.K})]$$

$$\Delta S^\circ_R = -146.5 \text{ J/K} = -0.1465 \text{ kJ/K}$$

$$\Delta G^\circ_R = \Delta H^\circ - T \Delta S^\circ$$

$$= -116.2 \text{ kJ} - (298 \text{ K})(-0.1465 \text{ kJ/K})$$

$$\Delta G^\circ_R = -72.5 \text{ kJ}$$

$\Delta G < 0$ R is spontaneous

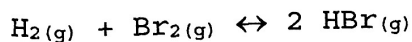
$$K = e^{-\Delta G^\circ / RT}$$

$$\frac{\Delta G^\circ}{RT} = \frac{(-72.5 \text{ kJ})}{(8.314 \times 10^{-3} \text{ kJ/mol.K})(298 \text{ K})}$$

$$= -29.3$$

$$K = e^{-(-29.3)} = \underline{\underline{5 \times 10^{12}}}$$

2. (a) Calculate the standard free energy (ΔG°) and the equilibrium constant (K) at 298K for the following reaction:



Is the process spontaneous as written?

HBr: $\Delta G^\circ_f = -53.22 \text{ kJ/mol}$ H_2 : $\Delta G^\circ_f = 0 \text{ kJ/mol}$ Br_2 : $\Delta G^\circ_f = 0 \text{ kJ/mol}$

- (b) If you have a reaction mixture with initial concentrations $[\text{H}_2] = 0.200\text{M}$ and $[\text{Br}_2] = 0.200\text{M}$, what are the equilibrium concentrations of H_2 , Br_2 , and HBr?

$$\begin{aligned} \text{(a)} \quad \Delta G^\circ_R &= \sum n \Delta G^\circ_f \text{ prod} - \sum n \Delta G^\circ_f \text{ react} \\ &= (2 \text{ mol} \times -53.22 \text{ kJ/mol}) - [(1 \text{ mol} \times 0 \text{ kJ/mol}) + (1 \text{ mol} \times 0 \text{ kJ/mol})] \end{aligned}$$

$$\Delta G^\circ_R = -106.4 \text{ kJ}$$

$\Delta G < 0 \Rightarrow R$ is spontaneous.

$$K = e^{-\Delta G/RT}$$

$$\frac{\Delta G}{RT} = \frac{-106.4}{(8.314 \times 10^{-3})(298)} = -42.9$$

$$K = e^{-(-42.9)} = \underline{4 \times 10^{18}}$$

$K \gg 1$ Products (forward R) favored

$$\text{(b)} \quad K = \frac{[\text{HBr}]^2}{[\text{H}_2][\text{Br}_2]} = 4 \times 10^{18}$$

$$\frac{(2x)^2}{(0.200-x)(0.200-x)} = 4 \times 10^{18}$$

$$\frac{2x}{0.200-x} = \sqrt{4 \times 10^{18}}$$

$$2x = \sqrt{4 \times 10^{18}} (0.200-x)$$

$$x = 0.2 \text{ M}$$

	$[\text{H}_2]$	$[\text{Br}_2]$	$[\text{HBr}]$
I	0.200	0.200	0
C	-x	-x	+2x
E	0.200-x	0.200-x	2x

$$[\text{H}_2] = [\text{Br}_2] = 0.200\text{M} - 0.2\text{M} = \underline{0 \text{ M}}$$

$$[\text{HBr}] = 2(0.2\text{M}) = \underline{0.4 \text{ M}}$$